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Investigations on mineral content in warty crab *Eriphia verrucosa* (Forskal, 1775) from the Rize Coast of Black Sea, Turkey

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ABSTRACT

This study investigated the seasonal variations in mineral content of edible parts of male and female warty crab *Eriphia verrucosa* (Forskal, 1775) distributed along Rize Coast of Black Sea and compared the same with the limit values of mineral content for human consumption set by various national and international standards. The contents of Al, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni and P estimated during the present study did not exceed the limit values as per the national and international standards. However, Pb (0.25-0.70 mg kg^{-1}), Se (0.29-0.75 mg kg^{-1}) and Zn (43.86-72.59 mg kg^{-1}) contents were found to be above the limit values. In terms of daily consumption values, it was found that, Al (1.86-3.35 mg kg^{-1}), B (2.17-3.65 mg kg^{-1}), Fe (2.80-6.44 mg kg^{-1}) and Mo (0.01-0.02 mg kg^{-1}) contents were within the limits as per all standards; while Ca, Cd, Cr, K, Mg, Mn, Na and P contents were above the limits prescribed by certain standards and Cu, Pb, Se and Zn contents were above the limits as per all the standards Most mineral contents of female crabs were higher than those of the males. Additionally, mineral content of the crabs was observed to increase during summer compared to other seasons.

Keywords: Black Sea, *Eriphia verrucosa,* Gender, Mineral content, Season, Warty crab

Introduction

Seafoods are one of the most important sources of healthy and balanced diet of which crustaceans are of significant economic importance due to the quality of edible meat. Crab meat is said to be an excellent source in terms of macro and micro elements such as calcium, iron, zinc, potassium, phosphorus, copper, manganese, zinc and calcium, in particular (Kucukgelmez *et al*., 2006; Chen *et al*., 2007; Kayhan *et al*., 2010; Jimmy and Arazu 2012).

The warty crab *Eriphia verrucosa* (Forskal, 1775) is an important species of crab in the Black Sea which is mostly consumed in the Aegean and Mediterranean coasts in Turkey. Total production of warty crab in Turkey in 2016 was 6 t (TUIK, 2016). The present study attempted to estimate the content of minerals. *viz.,* aluminum (Al), boron (B), calcium (Ca), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), molybdenum (Mo), sodium (Na), nickel (Ni), phosphorus (P), lead (Pb), selenium (Se) and zinc (Zn) in the warty crab caught in the Rize coast of the Black Sea. Nutritional value of crab meat in terms of human health and the metal pollution of the region were also assessed during the study.

Materials and methods

Study area and sampling

The study was carried out druing the period May 2012 to March 2013 in coastal areas of Rize Province in the Eastern Black Sea coast (between 41.05 N - 40.46 E, 41.03 N - 40.45 E, 41.05 N - 40.62 E, 41.06 N - 40.60 E coordinates). The crab samples for the study were collected from fishermen engaged in fishing, operating nets in the depth range of 10-20 m.

A total of 103 crab samples were used in the study. The samples taken seasonally were kept alive in styrofoam boxes with ice and brought to the Processing Technology Laboratory, Faculty of Fisheries, Recep Tayyip Erdogan University, Turkey. Crab samples were sorted into females and males, their length and weight measurements were taken using a digital caliper (Maher 16; with a precision of 0.1 mm) and a digital scale (And G-200 with a precision of 0.01 g) respectively. The carapace meat and claw meat of the crabs were picked by hand, pooled and the meat thus collected from 40 females (average weight 78.39±18.59 g) and 63 males (average weight 156.98±29.84 g) were labeled and preserved at 72°C until analysis.

Mineral content analysis

The crab meat samples were dried at 105°C, crushed in a porcelain mortar and 0.5 g sample was treated with 5 ml of nitric acid (65%) at room temperature for 24 h followed by incubation at 100°C 4 h. The acid treated samples were cooled to room temperature and filtered (Whatman no. 42). The filtered samples were made up to 25 ml with deionised water (Caglak and Karslı, 2014) and mineral contents were analysed in an inductively coupled

plasma optical emission spectrometer (Optima ICP-OES 7000 DV, Perkin Elmer). The sample preparation for analysis was carried out as per FAO technical report 158 (Bernhard, 1976; Zhang *et al*., 2007; Sukender *et al*., 2012). The wavelength frequencies (absorbance values) used for different elements were: Al - 396,153 nm, B - 249,677 nm, Ca -317,933 nm, Cd - 228,802 nm, Cr - 267,716 nm, Cu - 327,393 nm, Fe - 238,204 nm, K - 766,490 nm, Mg - 285,213 nm, Mn - 257,610 nm, Mo - 202,031 nm, Na - 589,592 nm, Ni - 231,604 nm, P - 213,617 nm, Pb - 220,353 nm, Se - 196,026 nm and Zn - 206,200 nm. The concentration of elements were calculated from dry weight and expressed as mg kg^{-1} wet weight.

Statistical analysis

SPSS 11.0 (SPSS, Inc., Chicago, IL, USA) software package was used for statistical analysis of the data. In order to test the significance of difference in mineral contents between males and females as well as between seasons, one way ANOVA and least significant difference 'LSD' test were applied ($p<0.05$) (Sumbuloglu and Sumbuloglu, 2000).

Results and discussion

Mineral contents of male and female crabs in different seasons recorded during the present study are presented in Table 1. Table 2 summarises the mineral content recorded in selected marine mollusc/crustacean species from different locations. The limit values for these minerals for human consumption set by various national and international standards are given in Table 3 and 4.

Aluminum (Al)

The lowest Al content observed in the present study was 1.86 mg kg^{-1} recorded in male specimens in spring season. The highest amount (3.35 mg kg^{-1}) was found in females in summer. Al levels recorded in the literature ranged between 1.2 - 58.7 mg kg^{-1} (Mutlu *et al*., 2011; Bordon *et al.,* 2012). As per the Agency for Toxic Substances and Disease Registry, USA (ATSDR, 2013) and the Joint FAO/WHO Expert Committee on Food Additives (JECFA, 1989), the consumption limit of Al is 1 mg kg^{-1} day^{-1}. Considering the average human weight of about 60-70 kg, Al content of warty crabs recorded during the present study has been found to pose no risk for human consumption.

Boron (B)

The highest value of boron (B) (3.65 mg kg^{-1}) was found in female crabs in summer, while the lowest value of 2.17 mg kg^{-1} was observed in males in autumn. Our results were found to be lower than the boron content of 6.70-19.89 mg kg^{-1} reported by Demopoulos *et al*. (2008) in *Scylla serrata*. Limit value of boron for human consumption has been specified as 0.2 mg $kg^{-1}day^{-1}$ (ATSDR, 2013) and the content recorded in warty crabs during the present study was not found to be at risk for consumption by human adults.

Table 1. Seasonal mineral contents of warty crab (mg kg^{-1} wet weight) (black: maximum, grey: minimum)

Minerals	Seasons							
	Spring		Summer		Autumn		Winter	
	Male	Female	Male	Female	Male	Female	Male	Female
Al	$1.86\pm0.60_{A}^{a}$	$3.16\pm0.92_{A}^{a}$	$2.09\pm0.04_{A}^{a}$	$3.35\pm0.14_{A}^{b}$	$2.59\pm0.11_{A}^{a}$	$3.24\pm0.35_{A}^{a}$	$2.17\pm0.05_{A}^{a}$	$2.83\pm0.15_{A}^{b}$
B	$2.28\pm0.06_{A}^{b}$	$2.52\pm0.37_{A}^{a}$	$2.50\pm0.09_{A}^{a}$	$3.65\pm0.42_{A}^{a}$	$2.17\pm0.57_{A}^{a}$	$3.54\pm1.38_{A}^{a}$	$2.29\pm0.15_{A}^{a}$	$2.69\pm0.12_{A}^{a}$
Ca	$773.73\pm296.67_{AB}^{a}$	$1102.62\pm408.45_{A}^{a}$	$1419.19\pm2.34_{A}^{a}$	$1364.89\pm193.09_{A}^{a}$	$411.15\pm174.09_{B}^{a}$	$1185.98\pm349.11_{A}^{a}$	$201.85\pm9.88_{B}^{a}$	$432.88\pm275.54_{A}^{a}$
Cd	$0.02\pm0.01_{A}^{a}$	$0.04\pm0.01_{A}^{a}$	$0.03\pm0.00_{A}^{a}$	$0.05\pm0.00_{B}^{b}$	$0.03\pm0.01_{A}^{a}$	$0.04\pm0.00_{AB}^{a}$	$0.03\pm0.00_{A}^{a}$	$0.03\pm0.00_{A}^{a}$
Cr	$0.05\pm0.02_{A}^{a}$	$0.05\pm0.01_{A}^{a}$	$0.15\pm0.11_{A}^{a}$	$0.10\pm0.01_{A}^{a}$	$0.31\pm0.04_{A}^{a}$	$0.13\pm0.01_{A}^{b}$	$0.35\pm0.23_{A}^{a}$	$0.11\pm0.01_{A}^{a}$
Cu	$7.29\pm1.31_{A}^{a}$	$8.03\pm0.06_{A}^{a}$	$7.30\pm0.88_{A}^{a}$	$7.91\pm1.10_{A}^{a}$	$5.29\pm0.32_{A}^{a}$	$8.03\pm0.20_{A}^{b}$	$5.12\pm0.20_{A}^{a}$	$4.75\pm0.56_{B}^{a}$
Fe	$2.80\pm0.75_{A}^{a}$	$6.44\pm4.95_{A}^{a}$	$2.64\pm0.31_{A}^{a}$	$4.10\pm0.09_{A}^{b}$	$3.37\pm0.25_{A}^{a}$	$5.26\pm1.62_{A}^{a}$	$3.26\pm0.45_{A}^{a}$	$2.86\pm0.14_{A}^{a}$
K	$1297.45\pm117.89_{A}^{a}$	$1180.1\pm65.47_{A}^{a}$	$1060.67\pm505.63_{A}^{a}$	$1961.83\pm30.15_{B}^{a}$	$1443.18\pm5.21_{A}^{a}$	$1811.17\pm116.37_{B}^{b}$	$1368.45\pm10.08_{A}^{a}$	$1479.99\pm23.62_{C}^{b}$
Mg	$225.64\pm17.92_{A}^{a}$	$241.15\pm13.52_{AB}^{a}$	$215.38\pm32.62_{A}^{a}$	$291.94\pm19.76_{A}^{a}$	$168.44\pm16.51_{A}^{a}$	$290.5\pm17.46_{A}^{b}$	$156.84\pm5.09_{A}^{a}$	$188.63\pm16.07_{B}^{a}$
Mn	$0.50\pm0.06_{AB}^{a}$	$1.93\pm0.41_{A}^{b}$	$0.86\pm0.20_{A}^{a}$	$1.75\pm0.24_{A}^{a}$	$0.62\pm0.06_{AB}^{a}$	$1.69\pm0.26_{A}^{b}$	$0.32\pm0.01_{B}^{a}$	$0.42\pm0.03_{B}^{b}$
Mo	$0.01\pm0.00_{A}^{a}$	$0.01\pm0.00_{A}^{a}$	$0.01\pm0.00_{A}^{a}$	$0.01\pm0.01_{A}^{a}$	$0.01\pm0.00_{A}^{a}$	$0.02\pm0.01_{A}^{a}$	$0.01\pm0.01_{A}^{a}$	$0.01\pm0.01_{A}^{a}$
Na	$1219.81\pm11.88_{A}^{a}$	$1276.04\pm0.95_{A}^{b}$	$915.2\pm118.09_{B}^{a}$	$1342.66\pm5.13_{A}^{b}$	$854.93\pm1.56_{B}^{a}$	$1338.48\pm47.43_{A}^{b}$	$788.99\pm5.04_{B}^{a}$	$949.86\pm32.86_{B}^{b}$
Ni	$0.01\pm0.00_{A}$	ND	$0.11\pm0.01_{A}^{a}$	$0.01\pm0.00_{A}^{b}$	$0.08\pm0.04_{A}^{a}$	$0.07\pm0.03_{A}^{a}$	$0.10\pm0.06_{A}^{a}$	$0.07\pm0.04_{A}^{a}$
P	$940.15\pm44.21_{A}^{a}$	$849.69\pm51.71_{A}^{a}$	$1156.1\pm37.96_{B}^{a}$	$1524.56\pm67.36_{B}^{b}$	$1038.74\pm60.43_{AB}^{a}$	$1283.02\pm10.75_{C}^{b}$	$941.16\pm33.77_{A}^{a}$	$967.29\pm8.22_{A}^{a}$
Pb	$0.25\pm0.03_{A}^{a}$	$0.43\pm0.10_{A}^{a}$	$0.34\pm0.08_{A}^{a}$	$0.70\pm0.36_{A}^{a}$	$0.35\pm0.11_{A}^{a}$	$0.55\pm0.14_{A}^{a}$	$0.27\pm0.05_{A}^{a}$	$0.32\pm0.05_{A}^{a}$
Se	$0.29\pm0.08_{A}^{a}$	$0.47\pm0.06_{A}^{a}$	$0.42\pm0.00_{AB}^{a}$	$0.75\pm0.00_{B}^{b}$	$0.56\pm0.06_{B}^{a}$	$0.56\pm0.01_{A}^{a}$	$0.43\pm0.01_{AB}^{a}$	$0.56\pm0.04_{A}^{b}$
Zn	$46.6\pm2.31_{A}^{a}$	$43.86\pm6.59_{A}^{a}$	$46.85\pm0.80_{A}^{a}$	$72.59\pm2.53_{B}^{b}$	$50.57\pm0.32_{A}^{a}$	$66.47\pm1.66_{BC}^{b}$	$49.42\pm1.00_{A}^{a}$	$54.56\pm3.29_{C}^{a}$

Different subscript upper case letters (A, B, C) in the same row represent significant differences ($p<0.05$) among different seasons for the same type of minerals in males or females. Different superscript lower case letters (a, b) in the same row represent significant differences ($p<0.05$) between males and females for same type of minerals in the same season.

Table 2. Mineral content of marine mollusc/crustacean species from different studies (mg kg^{-1})

Authors	Topcuoglu *et al*. (2002)	Gokoglu and Yerlikaya, 2003	Demopoulos *et al*. (2008)	Bat *et al*. (2009)	Barrento *et al*. (2009)	Bilgin and Fidanbas (2011)	Mutlu *et al*. (2011)	Bordon *et al*. (2012)	Julshamn *et al*. (2015)	Present study
Location	Rize	Antalya	Island of Kosrae	Sinop	Scottish coast	Egirdir	Mediterranean Lagoon	Santos Estuarine System	Barents Sea	Rize
Species	*Rapana venosa*	*Callinectes sapidus** *Portunus pelagicus*	*Scylla serrata*	*Eriphia verrucosa*	*Cancer pagurus*	*Potamon potamios*	*Callinectes sapidus*	*Callinectes danae*	*Paralithodes camtschaticus*	*Eriphia verrucosa*
Al							1.2-13.7	25.1-58.7		1.86-3.35
B			6.70-19.89							2.17-3.65
Ca		649-1492* 876-1509	3005.8-6893.4		240-9430 (M) 200-2850 (F)	8970-13530 (M) 9920-17870 (F)				201.85-1419.19
Cd	<0.02			0.18	ND-28 (M) ND-20 (F)		0.03-0.08	0.012-0.022	0.001-0.26	0.02-0.05
Cr	<0.06						0.05-0.13	0.005-0.500		0.05-0.35
Cu	15.61	25.3-31.3* 14.9-20.8	17.79-48.29	2.61	6.7-18 (M) 8.6-47 (F)	50-70 (M) 50-60 (F)	5.38-11.7	3.5-20.1		4.73-8.03
Fe	26.73	10.4-11.3* 4.5-6.8	47.47-78.74	2.54	3.2-23 (M) 3.7-18 (F)	20-50 (M) 30-60 (F)	21.1-38.2	6-21		2.80-6.44
K		2444-2563* 3038-3089	11338-16812		1670-3030 (M) 1620-3050 (F)	10760-11700 (M) 8930-10440 (F)				1060.67-1961.83
Mg		351-371* 488-558	2065.9-2673.5		210-500 (M) 300-390 (F)	1660-2080 (M) 1710-1860 (F)				156.84-291.94
Mn	0.97	3.7-3.9* 0.6-1.6	2.55-4.07	0.17	0.26-2.1 (M) 0.24-2 (F)		0.15-2.98	0.8-5.6		0.32-1.93
Mo										0.01-0.02
Na		2668-3269* 3198-3535	13885-17357		2240-3540 (M) 2230-3510 (F)	9500-11590 (M) 9760-77880 (F)				788.99-1342.66
Ni	1.57			1.42			0.24-0.45	0.00-0.03		0.01-0.11
P	<0.5	1352-1654* 1206-1542	8889.5-9973.5			740-900 (M) 760-950 (F)				849.69-1524.56
Pb				0.44	ND-0.03 (M) ND-0.03 (F)			0.003-1.725	<0.01	0.25-0.70
Se					1-1.5 (M) 0.83-1.9 (F)					0.29-0.75
Zn	18.44	47- 69.9* 37.2-46.8	286.49-335.55	10.1	17-74 (M) 22-70 (F)	200-210 (M) 180-230 (F)	13.9-20.1	20.1-33.8		43.86-72.59

M: Male, F: Female, ND: Not detected.

Table 3. Limit values of certain minerals in crustacean meat as per National and International Standards (wet weight basis)

References	Minerals																
	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	Se	Zn
TKB. KKGM. Seafood quality control handbook (2000) (mg kg^{-1})	-	-	-	1	-	20	-	-	-	-	-	-	-	-	2	-	50
Turkish food codex legislation (2002) (mg kg^{-1})	-	-	-	0.5	-	20	-	-	-	-	-	-	-	-	0.5	-	50
Turkish food codex legislation (2011) (mg kg^{-1})	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	0.5	-	-
FDA (2007) (ppm)	-	-	-	3	12	-	-	-	-	-	-	-	70	-	1.5	-	-
EC (2007) (mg kg^{-1})	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	0.5	-	-
FSANZ (2005) (mg kg^{-1})	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25-40
FAO (Nauen, 1983) (legal limits in countries) (ppm)	-	-	-	0.05-5.5	1	10-100	-	-	-	-	-	-	-	-	0.5-10	0.30-2	30-1000

Table 4. The consumption limit values of certain minerals as per International standards (wet weight basis)

References	Minerals																
	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	Se	Zn
ATSDR (MRLs) (2013): Oral (mg kg day^{-1}) Inhalation (mg m^{-3})	1.0 Or.	0.2 Or.		0.0003 Or. Av.	0.005 Or.	0.01 Or.				0.0003 Inh.			0.0002 Inh.			0.005 Or.	0.3 Or.
EPA (2000) (mg kg day^{-1})				0.001												0.005	
China Nutrition Institute (2001) (mg day^{-1}) Chen *et al*.(2007)			800			1.0	12	1500	150	3.5		900		500			12
RDA (mg day^{-1}) (NAS, 1989)						0.9	8 (M&F>51 yrs) 18 (F 19-50 yrs)				0.045					0.055	11(M) 8 (F)
AI (ages 19-50 mg day $^{-1}$) The U.S. Food and Nutrition Board of the Institute of Medicine (Goldhaber, 2003)					0.035 (M) 0.025 (F)					2.3 (M) 1.8 (F)							
JECFA (mg kg day^{-1}) FAO/WHO (1978; 1982; 1983; 1989)	1.0			0.001		0.5	0.8								0.0035		1.0
FDA (2013) (mg day^{-1})			1000		0.12	2	18	3.500	400	2	0.075	2400		1000		0.07	15

Av: Average, M: Male, F: Female. Or: Oral, Inh: Inhalation

Calcium (Ca)

Daily intake of Ca, which has an important place in human diet, has been specified by China National Institute (Chen *et al*., 2007) and FDA (2013) as 800 mg and 1000 mg, respectively. The highest Ca content of 1419.19 mg kg^{-1} was recorded in male crabs during the present study in summer. The lowest value (201.85 mg kg^{-1}) was found again in males in winter. Our results were found to be within the range reported in *Cancer pagurus* (200-17870 mg kg^{-1}) by Barrento *et al.* (2009) and lower than that reported by Bilgin and Fidanbas (2011) in *Potamon potamios*. Although some of our values seem to be high in terms of daily consumption, the differences are not expected to pose a risk to human health.

Cadmium (Cd)

Highest Cd content was recorded for females (0.05 mg kg^{-1}) in winter, while the lowest value of 0.02 mg kg^{-1} was recorded in males during spring. Cd values observed by us were within the consumption values given by EPA (2000) and JECFA (1989), while the levels were found to exceed the limits specified by ATSDR (2013), considering average human weight of 60-70 kg. Cd contents recorded in our study were found to fall within the range as reported in literature (Barrento *et al*., 2009; Julshamn *et al*., 2015).

Chromium (Cr)

In the present study; the highest value of Cr was determined in male crabs at 0.35 mg kg^{-1} in winter and the lowest value of 0.05 mg kg^{-1} was recorded during spring in both sexes. The values were found to be within the range (0.005-0.5 mg kg^{-1}) reported by Bordon *et al.* (2012). The Cr content of warty crab recorded during all the seasons were found to be below the limit value specified by FDA (2007) and FAO (Nauen,1983). However, the values of male and female crabs were found to be above the daily consumption levels specified by the U.S. Food and Nutrition Board of the Institute of Medicine (Goldhaber, 2003).

Copper (Cu)

The highest Cu value was observed in females (8.03 mg kg^{-1}) in autumn and the lowest value (4.75 mg kg^{-1}) again in females in winter and the values were within the ranges reported by Bat *et al*. (2009) and Bilgin and Fidanbaş (2011). It was found that the limit values specified in Table 3 did not exceed our values.With respect to the daily consumption, results of the present study were found to be above all the specified limit values except those by JECFA (1989).

Iron (Fe)

Iron was found to be lowest in males (2.64 mg kg^{-1}) in summer and the highest value of 6.44 mg kg^{-1}

was found in females in spring. In previous reports, Fe content ranged between 2.54-78.74 mg kg^{-1} (Demopoulos *et al.,* 2008; Bat *et al*., 2009). The values obtained in the present study are within this range. The Fe content determined in the present study was found to be under the recommended dietary allowance (RDA) set by NAS (1989).

Potassium (K)

The highest amount of K (1961.83 mg kg^{-1}) was found in females during summer and the lowest (1060.67 mg kg^{-1}) in males again in summer. Potassium content in the range between 1620-16812 mg kg^{-1} has been rported in various studies (Demopoulos *et al*., 2008; Barrento *et al*., 2009). With respect to daily consumption, the potassium levels in warty crab recorded during different seasons for males and females in the present study, except those for summer-female and autumn-female were found to be below the values specified by China Nutrition Institute (Chen *et al*., 2007) and FDA (2013).

Magnesium (Mg)

Highest value of 291.94 mg kg^{-1} was measured in females in summer and the lowest (156.84 mg kg^{-1}) in males in winter. These values were found to be less than the Mg contents content (300-390 mg kg^{-1}) of female *Canger pagurus* reported by Barrento *et al.* (2009), while these were within range of 210-500 mg kg^{-1} found in males. In terms of daily consumption values, data of the present study were found to be above the values specified by China Nutrition Institute (Chen *et al*., 2007), but below those specified by FDA (2013).

Manganese (Mn)

The highest Mn content (1.93 mg kg^{-1}) was observed in females in spring while the lowest value (0.32 mg kg^{-1}) was found in males in winter. The amount of Mn was determined to be between 0.15-5.6 mg kg^{-1} (Mutlu *et al*., 2011; Bordon *et al.,* 2012). With respect to the daily consumption limits specified for Mn, the content of Mn in warty crab was found to be within the limit values specified by the U.S. Food and Nutrition Board of the Institute of Medicine (Goldhaber, 2003). The limit specified by ATSDR was not assessed as it is expressed in terms of inhalation.

Molybdenum (Mo)

In the analyses performed with respect to season and gender; Mo content in the range of 0.01-0.02 mg kg^{-1} were recorded. No previous studies specified the limit for Mo content in seafood. Examining the daily consumption values, the data from the present study were found to be below the values specified by FDA (2013).

Sodium (Na)

While Na content in females in summer (1342.66 mg kg^{-1}) indicated the highest level, the lowest (788.99 mg kg^{-1}) was observed in males in winter. The results from the present study were observed to be lower than the the range of 2230-77880 mg kg^{-1} reported by Barrento *et al*. (2009) and Bilgin and Fidanbas (2011). Our results, were found to be above the daily consumption values specified by China Nutrition Institute (Chen *et al*., 2007) while, below the limits specified by FDA (2013).

Nickel (Ni)

While the amount of Ni was found to be below the detection limits in females, the highest levels were measured in males (0.11 mg kg^{-1}) in summer. Ni amounts were determined to be between 0.00-1.57 mg kg^{-1} in the previous studies (Topcuoglu *et al*., 2002; Bordon *et al*., 2012). Also, the results of the present study were found to comply with both limit value standards and daily consumable amount standards.

Phosphorus (P)

The highest value was measured in females (1524.56 mg kg^{-1}) in summer and the lowest value again in females (849.69 mg kg^{-1}) during spring. The results of the present study were observed to fall within the range of 740-9973.5 mg kg^{-1} reported by Bilgin and Fidanbas, (2011) and Demopoulos *et al*., (2008). All of our data were found to be higher than the values specified by China Nutrition Institute (Chen *et al*., 2007) in terms of daily consumption amounts and some of them were found to be higher than the value specified by FDA (2013).

Lead (Pb)

The highest value for Pb was measured in females at 0.70 mg kg^{-1} in summer and the lowest value in males (0.25 mg kg^{-1}) in spring. All the values in the present study were found within the range of 0.003 to 1.725 mg kg^{-1} of lead as reported by Bordon *et al*. (2012). Pb amounts of both male and female were found below national and international standard values (Table 3), except for those of the female crabs in summer and autumn. The data in the present study were found to be higher than the daily consumable amount of 0.0035 mg $kg^{-1}day^{-1}$ specified by JECFA.

Selenium (Se)

The highest amount of selenium was found in females at 0.75 mg kg^{-1} in summer and the lowest amount in males (0.29 mg kg^{-1}) in spring. The Se values obtained were lower than the range of 0.83-1.9 mg kg^{-1} reported by Barrento *et al*. (2009). In the regulation specified by FAO

(Nauen, 1983), where limit values of several countries were given, the maximum value for Se was specified as 2 mg kg^{-1}. Examining Table 4, in which daily consumption amounts are given, it is seen that the data of the present study were above the specified values except for ATSDR (2013) and EPA (2000).

Zinc (Zn)

In the present study; the highest value of Zn was found in females (72.59 mg kg^{-1}) in summer and the lowest in males (43.86 mg kg^{-1}) in spring. Zn values from earlier studies varied in the range of 10.1-335.55 mg kg^{-1} (Demopoulos *et al*., 2008; Bat *et al*., 2009). Our data were found to be higher than the limit values (25-40 mg kg^{-1}) specified by FSANZ (2005) and the values in summer, autumn and winter in females and in autumn in male were found to be higher than the limit value (50 mg kg^{-1}) specified by TKB (2000) and Turkish Food Codex Legislation (2002). In terms of seasonal and gender differences, our results were found to be above the daily consumable limit value. Since the benefits of zinc and inadequate consumption by the Turkish people (Taneli, 2005) are well-known, it is expected that the consumption and limit values might not pose a problem considering the crab consumption habits.

In the present investigation, the levels of B, Na and Se recorded in warty crab were found to be lower than those reported in earlier studies. Al, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Ni, P, Pb and Zn levels were found to be with in the range reported in other studies.. In terms of the limit values specified in national and international standards; it was found that Al, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P and Se levels recorded in the present study did not exceed the limit values; but Pb and Zn values were found to be above the limits. In terms of daily consumption values; Al, B, Fe, K, Mn, Mo and Ni levels were found to be within the limit as specified by all standards. It was also observed that Ca, Cd, Cu, Mg, Na and P levels were above certain standard values; while Cr, Pb, Se and Zn levels were above the limit values specified by all standards. Fourteen minerals were found higher in females while 3 minerals were higher in males. Seasonally, mineral content were observed to be higher in summer, and lower during winter and autumn. A balanced diet of crab meat in Rize Province is expected to eliminate the mineral deficiencies in humans.

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